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The Robot

The Robot section of the 2003 FIRST Robotics Competition Manual provides:

- Information about the parts provided in the Kit of Parts,
- Information about additional parts that may be used to build the robot,
- Power distribution on the robot,
- Wiring examples,
- The rules governing robot design and construction,

Please read the Manual carefully and often.

NOTE: Documentation for the Robot Control System is provided by the manufacturer, Innovation First, and can be found on their web site at:

www.innovationfirst.com/firstrobotics/

Before embarking on the robot design process it is important to understand that there are certain rules and constraints on the robots that you must observe in order to compete successfully. The reasons for the rules and constraints are many and varied. We want to make sure that:

- FIRST Robotics Competition events are **SAFE**,
- All teams use provided and purchased materials according to established guidelines,
- Teams follow certain good design practices,
- The teams are presented with an intentional design challenge,

1 ROBOT GENERAL INFORMATION

Before you start construction be sure to have a thorough understanding of all the competition requirements. The complete and detailed list of rules governing robot design and construction is included in this section. Listed below are some of the more important requirements of these rules.

1.1 Materials Use Overview

The materials that you are allowed to use to build the robot are limited by certain rules. These rules can be found in Section 4 - Robot Rules.

Contact information for the suppliers of the parts provided in the Kit of Parts and other sources of material will be provided at a later date.

1.2 Rules Overview

By taking the time to read through the rules carefully you will save time in the long run. You can waste major blocks of time during the design process because of your lack of knowledge about a certain rule.

It is very important to become familiar with the Robot rules in Section 4. Keep the following in mind:

- The ***Rules of Game Play*** listed in the Game Section of the Manual
- ***Shipping Deadlines*** listed in the appropriate Events Sections.

1.2.1 Pay special attention to the items listed below.

- The *maximum size of the robot* is 30 inches (76.20cm) wide by 36 inches (91.44cm) long by 60 inches (152.40cm) high.
- The *maximum weight of the robot* is to 130.0 pounds (58.97 kg).
- For Safety reasons, certain uses of allowed materials are disallowed. See attached Acceptable Part Flowchart (Figure 4.1) to determine if a proposed part or material is allowed.
- Proper wiring of all electrical components is mandatory. See the *2003 FIRST Power Distribution Wiring Diagram* for proper circuit protection, device sequence, and wire size for specific motors, controls, and other components.
- All robots must pass inspection for compliance with all rules before being allowed to compete at each event.
- Check robot size and weight before shipping. There should be no need to perform major size and weight reductions as a result of failed inspection at a competition.

1.2.2 Questions?

- If you have a rules compliance question, consult this Manual and the Team Updates at: www.usfirst.org/robotics/2003/updates.htm
- If you do not find the answer to your question there, check the FIRST web site for links to competition message boards. Ask for help on the competition message boards. When asking a question, FIRST requires that you refer to a *specific* part of the Manual to which your question is directed.
- If you still do not find the answer to your question, find contact information in the Administrative Section of this Manual.

1.3 Scheduling Overview

Develop your overall planning and construction schedule to allow time for *robot testing* and *robot operator training*. Give your robot operators as much driving practice as possible.

This year's kit provides all of the major parts necessary to build a simple robot consisting of a frame, motors, drive train, wheels, battery, and controls. Within one week, it should be fairly easy to produce a controllable base platform to start operator training. If you have not built some sort of simple, drivable robot by the end of the second week of construction, you are behind schedule.

1.4 Team Updates and Message Boards

Team Updates will be available on the FIRST web site. In addition to the updates, FIRST will be using message boards to allow teams to ask questions and receive answers. Assign several team members to *carefully* read and interpret the Manual, Team Updates, and message boards.

In order to ensure that all teams have the *same* understanding of the rules, corrections, addenda and other important information, the Team Updates will summarize questions and answers from the competition message boards. When posting questions to the message boards, keep in mind that the same question may be asked in many ways. *Be sure to read the existing postings before submitting your own questions to see if there is already an answer to your question.*

2 ROBOT CONSTRUCTION

It is necessary to gain a thorough understanding of the capabilities of the various components in the Kit of Parts.

2.1 Motors

Selection of the proper motors to perform specific functions such as turning wheels, lifting arms and squeezing claws is a basic and essential part of the design process.

The motors supplied with the Kit of Parts have various power and speed capabilities. Some are quite powerful and draw very high current when loaded to their limits. Others have very high-speed capability. Some have integral transmissions that magnify their torque output. Some are equipped with selectable two-speed transmissions. Before choosing a motor for a particular use, be sure you thoroughly understand the characteristics of the motor.

Drill motors have an internal cooling fan that is not effective at low motor speeds. Do not operate the Drill motors at the stall condition because they will quickly overheat and fail.

As a general rule, design robot transmissions and gear ratios so that drive motors will not be operated beyond the current draw level of their maximum output power point. Verify this by monitoring motor current during robot design verification testing.

2.2 Motor Mounting

Many of the motors supplied in the kit of parts were not originally designed to be used as robot drive motors. The motor shafts on the drill and Globe motors were designed to provide axial torque only. They have very little ability to sustain *side loads* imposed on their motor shafts. *Take care to securely fasten these motors and couple them with flexible couplings to the rest of the drive train when they are used for motive power.*

2.3 Drive Train Construction

The Drive Train consists of those components that connect the drive motors to the wheels or tracks of the robot. Design your drive train so that the weight of the robot is supported by axles and shafts *and not* by the drive shafts of the motors. Incorporate sufficient gear reduction into the drive train to provide ample robot speed and sufficient drive torque. Use bearings and bushings to provide proper shaft support and minimize friction. Remember, *the more the robot weighs, the more internal friction will be experienced by the drive train components.* Align mechanical power transmission components accurately. *If you couple a motor shaft to another shaft, support the coupled shaft with bearings at two points, and use a flexible coupling to connect it to the motor.*

FIRST recommends using the Kit-provided motor mounts, drive train mounts, shafts, gears, couplings and connections, to provide proper speed reduction and power transmission between the motors and the robot traction load.

2.4 Use of Two-Speed Drill Motor Transmissions

The Drill motor assembly consists of the motor, a two-speed planetary gear reduction transmission, and an adjustable clutch.

The motor is a high-speed brush-type motor specifically suited to drive the transmission. Although it is not recommended, you may easily remove the motor from the transmission and use it separately. Thoroughly understand the internal workings of these units.

The two-speed transmission is capable of operating at 0-450 RPM in low speed range and 0-1500 RPM in high-speed range. If you plan to utilize both speeds (shift the transmission), be sure that the drill motor is stopped before shifting gears. Also, be sure to fully engage and securely hold the gear select sleeve in each speed range setting. If you plan to use only one speed range, fasten the gear select sleeve securely to prevent it from slipping out of gear.

The clutch is adjustable and can be set to disengage under different load conditions or not at all. *If not set properly, the clutch will slip under a lower load than required.* The clutch housing contains two back drive preventer pins that prevent the motor shaft from manually being turned (back driven).

These pins may be removed, allowing the motors to be back-driven by the robot's momentum in an un-powered state.

2.5 Motor Electrical Overload Protection

When installed properly, the Drill motors and CIM motors are protected by 40 Amp auto-resetting circuit breakers. Since the motors are capable of drawing over 100 Amps at stall torque, operating the motors at high torque for more than a few seconds will trip the auto-resetting circuit breaker. As soon as the circuit breaker cools sufficiently, it will reset and the motor will resume operation. Sudden acceleration, pushing/pulling, climbing sloped surfaces, turning and rapid change of forward-reverse direction require high motor torque and could overload the circuit breaker.

It is essential to select drive train gear ratios that keep the motor torque requirements within the protection limit of the circuit breaker. Circuit breaker protection is required to help prevent burning up the motors, controllers, and wiring system.

2.6 Drive Train Friction

Make every effort to make the robot drive train as friction-free as possible. Friction will develop at every surface-to-surface contact in the drive train.

Wherever possible, use rolling element bearings. Make sure you lubricate parts properly.

2.7 Best Practices in Robot Design

- A robot that is so fast that it is difficult to steer is probably geared too high. Use appropriate gear ratios and/or control system settings to achieve optimum performance of the drive train.
- Securely fasten and lock all drive gears, sprockets, pulleys and other components subject to slippage. Setscrews eventually slip. Keys and pins work better. Do not use a pin that is so large that its hole size compromises the cross sectional area of a shaft.
- Position the 12 Vdc battery within your robot so that it is accessible and can be easily changed out between matches. Fasten the battery securely in place so that it does not fall out of the robot or become disconnected during competition.
- Install electrical and control wiring so that it is *laid out logically* and *managed* with tie-wraps, spiral tubing, or shrink tubing.
- Protect your robot control system. A system left unprotected may be damaged during competition.
- Know your robot thoroughly. If something goes wrong during the competition, you usually have very little time to figure out the problem *and* fix it.
- Realize the limits of the motors and other parts. If you modify parts, make sure that there is still sufficient strength in the remaining part to mount it securely and have it function properly.
- As motors experience load, they turn into heaters and lose efficiency. *Keep motors cool by installing them in open areas or installing cooling fans.*
- Make sure that your robot can still turn if forced up against a wall or barrier. Tracked vehicles may not turn when the tracks are aligned against a wall.

3 ROBOT ELECTRICAL SYSTEMS

This section covers *power distribution* and *wiring rules* for the Robot Controller and Operator Interface system. It gives examples of how to wire parts included in the Kit of Parts to the Innovation First Control Systems.

Please note that Innovation First provides control system documentation on their web site at:

www.innovationfirst.com/firstrobotics/

WARNING!

Please read this and the following sections very carefully.

Failure to wire your robot properly could result in personal injury, damage to the control system, or damage to your robot. It could invalidate the control system warranty. FIRST and/or Innovation First will not provide free replacement of components damaged due to misuse or improper wiring. Teams will be required to correct wiring that is not configured according to this section and the control system rules in Section 3.2 and 3.3 before being allowed to compete.

3.1 Batteries and Chargers

Teams are responsible for managing the power consumption of their robot and for ensuring that their batteries are sufficiently charged to compete in each match. It is estimated that each battery can store sufficient energy to power a robot for at least 5 matches. It should not be necessary to swap batteries after each match.

3.1.1 Charging Your Battery

Teams must charge their batteries at their pit stations at each FIRST Robotics Competition event. For instructions on charging the batteries, please refer to the battery charger documentation included in the Kit. You may use additional battery chargers as long as their charging rate is no greater than the one provided in the Kit of Parts.

NOTE: If you have a battery that you know is damaged, please do not put it in the trash. Immediately replace and properly recycle the damaged battery.

WARNING!

Allow a warm battery to cool before charging. Please do not attempt to cool a battery by immersing it in ice, water, or snow. A battery that has been left out in cold weather must be allowed to reach room temperature before charging. Failure to do so will cause serious damage to the battery and may leak toxic liquid as a result. Be careful to avoid shorting the batteries. Short-circuit current exceeds 200A and can cause fire, serious injury, and leakage of toxic fluids.

3.1.2 Battery Recommendations / Cautions

- To connect the battery to the rest of the control system, FIRST recommends using ring terminal contacts and the red Anderson Power Products connectors. This allows for easy connection and disconnection of batteries in the robot.
- Although rare, the impact forces that robots sometimes experience during matches have been known to cause the Anderson Power Products connectors to disconnect. FIRST recommends utilizing a quick-release fastener, such as a Velcro strip, to hold the power connectors together during a match.
- When connecting the battery, be very careful to observe the proper polarity in order to prevent damage to control system components.

- During any match, only one of the 12 Volt Direct Current Sealed Lead/Acid (SLA) batteries supplied by FIRST may be used to power the robot. You may charge the batteries through the normal operation of the battery charger that FIRST provides.

3.2 Wiring the Robot Controls

3.2.1 Power Distribution Circuits

All electric current used on the robot must be conducted via wires or electrical paths through electrical components. *No part of the robot, such as the chassis or superstructure shall be used for this purpose.* All Common (-) circuits must be returned to the negative terminals of the power distribution circuit breaker panels via appropriately sized wire.

The 120A main circuit breaker/disconnect switch functions *both* as the Main power on/off switch for the robot *AND* as a safety current overload protection device.

Shut off robot power manually by pushing the RED BUTTON on the breaker. Turn power back on by pushing the RESET lever back into position.

You must wire the 120A circuit breaker/disconnect switch supplied in the Kit of Parts in series with the *positive (+) terminal* on the 12Vdc battery. Do not connect anything other than the 120A main circuit breaker/disconnect switch directly to the 12Vdc battery positive (+) terminal.

Insulate both positive (+) and negative (-) battery terminals with electrical tape.

The battery, 120A main circuit breaker/disconnect switch, and the three provided power distribution-circuit breaker panels may only be connected with the AWG #6 wire provided in the kit. Protect all branch circuits by circuit breakers as shown in the table below.

The circuit breaker current ratings indicated for specific circuits are the *maximum* allowed, and the AWG wire sizes are the *minimum* allowed. The Maxi, 8-position circuit breaker block will only hold the 40A Maxi auto-resettable circuit breakers. The 20A and 30A auto-resettable circuit breakers must be used in the two provided 12 position circuit breaker panels.

Table 3.1 Robot Circuits

Circuit	Power Source/Device
Battery Circuit	Electric power from a 12Vdc battery passes through a 120A main circuit breaker/disconnect switch to the circuit breaker/fuse panels.
Robot Controller, Relay Module, Fan, LED, Optical Sensor, Custom circuits	Power is distributed from the circuit breaker/fuse panels via 20A auto-resetting breakers to these devices.
Speed Controller Circuit	Power is distributed from the circuit breaker/fuse panels via single 20, 30 or 40A auto-resetting circuit breakers to the Speed Controllers (see table 3.2 for required breaker size)
All other electrical devices circuits	Sensors, motors, the rotating light, air valves, and the air pump receive power from either the Robot Controller, Relay Modules, or Speed Controllers <u>as described below</u> .

WARNING!

Be very careful to avoid short circuits!

The 12Vdc SLA batteries can deliver current in excess of 200 Amps for a sustained period of time (minutes). In a short circuit situation, this amount of current can make wires turn red hot and melt through their insulation in a fraction of a second, and can result in serious burns, scars, or other injuries. Short circuits can also destroy control system components, cause fires, or cause the battery to leak highly corrosive acid or explode. Always make sure that the 120A main circuit breaker/disconnect switch is wired in series with the battery positive (+) terminal.

It is *unlikely* that the new (for 2003) main circuit breaker/disconnect switch will trip to “off” as a result of the large impact forces sometimes experienced by robots in competition matches.

FIRST recommends protecting the top of the breaker and the mechanical trip release. Power from the battery must be distributed via the three circuit breaker/fuse panels included in the kit.

Note that: Two of the circuit breaker/fuse panels each contain 12 protected (via the 20A or 30A Snap-Action circuit breakers) outputs connected to one input. On each panel, there is also a 12 position unfused block that is isolated from the fused portion of the panel. This unfused block is intended to act as a Common (-) terminal. Do not short circuit the Common (-) terminal to the 12Vdc (+) terminals of the circuit breaker/fuse panel. A third (Maxi style) circuit breaker panel is provided that contains 8 positions to accommodate the larger size 40A Snap Action breakers. Only 4 of those positions are to be used. These 4 positions have been pre-wired with AWG#10 wires that connect individually to the internal Maxi style breaker sockets.

The 2003 FIRST Power Distribution Wiring Diagram shows an example diagram for power distribution.

The 2003 FIRST Power Distribution Wiring Diagram shows more relay modules and speed controllers than are included in the Kit of Parts in order to show how devices may be connected on your robot. Additional relay modules and speed controllers may be obtained by purchasing them from Innovation First.

Except as noted herein, each Ground (GND) wire from a speed controller, relay, or Robot Controller must go directly from that item to one of the 12 Common (-) terminal tabs on the circuit breaker/ fuse blocks.

Exception: The Ground (GND) wires from low current items such as solenoid control and rotating light relays, custom circuit, optical sensors, LEDs, and fans may be connected as a group to one common wire leading back to a Common (-) terminal tab.

CAUTION!

Check wiring periodically!

Be sure to check the wiring on a periodic basis to prevent failures that could harm the control system or cause a robot to stop dead in the middle of a match. Crimp-on connectors that are improperly crimped may work at first, but can fail easily due to the normal operating vibration of a robot. Also, be sure to avoid tension on the wires when components are installed on the robot and never remove a connector by pulling on the wire. Improper or abused connections can result in poor performance, intermittent failures, and/or short circuits.

- *FIRST recommends that all wiring be laid out in a logical orderly manner and be managed by the use of plastic quick ties, shrink-wrap tubing or plastic helical wire wrap. The wiring scheme should be easy to trace and interpret during technical inspection.*
- *It is advisable to produce a wiring diagram for reference. This would greatly facilitate solving any electrical problems.*
- *It is also advisable to label wires and devices to facilitate tracing and reconnecting wiring.*

All wires distributing power with a constant polarity (i.e., not an output from a Relay Module, Speed Controller, or Sensor) *must be color-coded as follows:*

- Use Red or White wire for +12 Vdc and +5 Vdc.
- Use Black wire for Common (-).

The wires and cables included in the Kit are intended for specific uses. Table 3.2 shows the minimum wire sizes allowed for hookup of the various control system devices.

Table 3.2: Minimum Wire Size and Protection by Device Type

Device	Wire Type	Circuit Breaker
Power distribution from battery through 120A Main Circuit Breaker/Disconnect Switch to fuse panels	6 AWG/red & black	120A
Drill motors, CIM motors; Speed Controllers used with Drill motors and CIM motors.	10 AWG/red & black	40 A
Fisher-Price motors, Van Door motors, Globe motors; Speed Controllers used with Fisher-Price Van Door, or Globe motors	10 AWG/red & black	30A
Robot Controller power, Relay Modules, Rotating Light, window motors, pump, solenoids, large muffin fan; Speed Controllers used with window motors	16 AWG/2 conductor	20A Relay Modules have 20 fuses
All switches, PWM cables, optical sensors, potentiometers, yaw rate sensor, LEDs, small muffin fans, custom circuits	24 AWG/2 or 3 wire conductor	Requirements vary

It is acceptable to shorten or lengthen Control System cables containing 3 or fewer wires as needed as long as the following conditions are met:

- The connection is insulated.
- The proper wire type is used. (As specified above)

This means, for example, that you may use 24 AWG wire to lengthen a PWM/Relay cable.

Other devices that may be connected directly to the fuse panel (Robot Controller, Fans, etc.) must be connected via a 20A circuit breaker. The same breaker may power all these devices. The 12 Vdc panel mounted LEDs provided in the Kit are intended to be used on the robot as indicator lamps and may be used on Speed Controller or Relay Modules outputs alone or in parallel with any other devices. You may also power the LEDs directly from an auto-resetting breaker.

3.2.2 Rotating Light

You must use a Relay Module to power the rotating light provided in the Kit. The light must turn “on” when the robot is enabled and must turn “off” when the robot is disabled. The control system will provide this function automatically when a Relay Module is connected to relay output 8 on the Robot Controller and the default program is running. Wire the light such that the black power lead is connected to the M- terminal and the red power lead is connected to M+ terminal on the Relay Module.

3.2.3 Relay Modules

For information about the Relay Modules, refer to the document *Spike Users Manual* from Innovation First website.

WARNING!

Attempting to drive the Drill motors, Van Door motors, Globe motors or Fisher-Price motors directly with the Relay Modules could damage the Relay Modules and is, therefore, prohibited.

Because of their high current requirements, the Drill motors, CIM motors, Fisher-Price motors, Globe motors, and Van Door motors *must be powered only by the Speed Controllers*.

You may use the Relay Modules to control the window motor, the rotating light, air pump, muffin fans, and pneumatic valves.

Under certain circumstances, it is acceptable to power more than one device from a single Relay Module. A single Relay Module may power no more than one motor or Pump. A single Relay Module may be used to power valves and/or fans in conjunction with a single window motor, pump or rotating light. Each Speed Controller must receive power via a dedicated 20A, 30A or 40A circuit breaker. Each Relay Module must receive power via a 20A circuit breaker. It is acceptable to distribute power from a single 20A circuit breaker to multiple Relay Modules if no more than one of the following devices is powered via the single 20A breaker:

- Air Pump
- Rotating light
- Window motor

The Spike Relay modules have a 20A fuse installed onboard. This fuse may be replaced with a 20A circuit breaker when the Relay Module is used to control the air pump. This Relay Module must still be fed from a 20A circuit breaker at the breaker panel.

To achieve control of both solenoids on a double solenoid valve, use only *one* Relay Module, and avoid running separate power return leads, use two diodes (max: 1A, 50V; peak rev.) to route power to one solenoid at a time. Figure 3.1 shows the schematic for this arrangement.

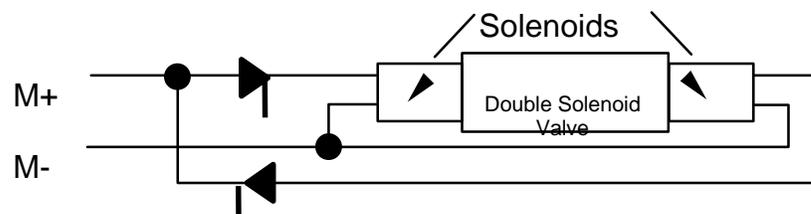


Figure 3.1 Use of Diodes with Double Solenoid Valve

3.2.4 Speed Controllers

For information about the Speed Controllers, refer to the document *Victor 883/884 Users Manual* on the Innovation First website.

WARNING!

The Speed Controllers will be damaged if reverse polarity is applied to the power inputs. Please be careful when wiring the Speed Controllers.

3.2.5 Muffin Fans

12Vdc muffin fans are included in the Kit. FIRST recommends installing these fans to direct cooling air over the components that run the hottest (high use motors). You may provide constant power to the fans directly via a 20A circuit breaker or use a Relay Module to switch power to the fans.

WARNING!

The muffin fans provided in the kit are not reversible. You can damage them if you apply reverse polarity. Please be careful when wiring the muffin fans.

3.2.6 Sensor Inputs on the Robot Controller

Within the rules, as described below, and according with the documentation supplied by Innovation First, teams may use sensor devices to create a custom sensor system on the robot. Innovation First specifies example wiring configurations for sensor inputs connected to the Robot Controller. Refer to Figure 3.2 for details concerning wiring sensors, switches and other devices to the **digital** or **analog** input terminals on the Robot Controller.

WARNING!

Do not connect switches to the +5Vdc Analog Input Pin (Pin 1) of the Robot Controller. It may damage the switches. Analog Input Pin 1 is intended to supply fused 5Vdc power for use by the Yaw Rate Sensor.

WARNING!

Do not connect any voltages greater than +5Vdc to the analog inputs on the Robot Controller. It may damage the Robot Controller.

Figure 3.2 shows an example of the proper way to connect a pressure switch, limit switch, and optical sensor to the **digital inputs** of the **Robot Controller**. It also shows an example of how to connect a potentiometer or yaw rate sensor to the **analog inputs** of the **Robot Controller**. Pin selection should conform to the *Pinout and Software Function Schedules* included in the Innovation First, Inc. *Robot Controller Reference Guide*. Pin designations shown in Figure 3.2 are examples and will vary depending on the number of devices connected.

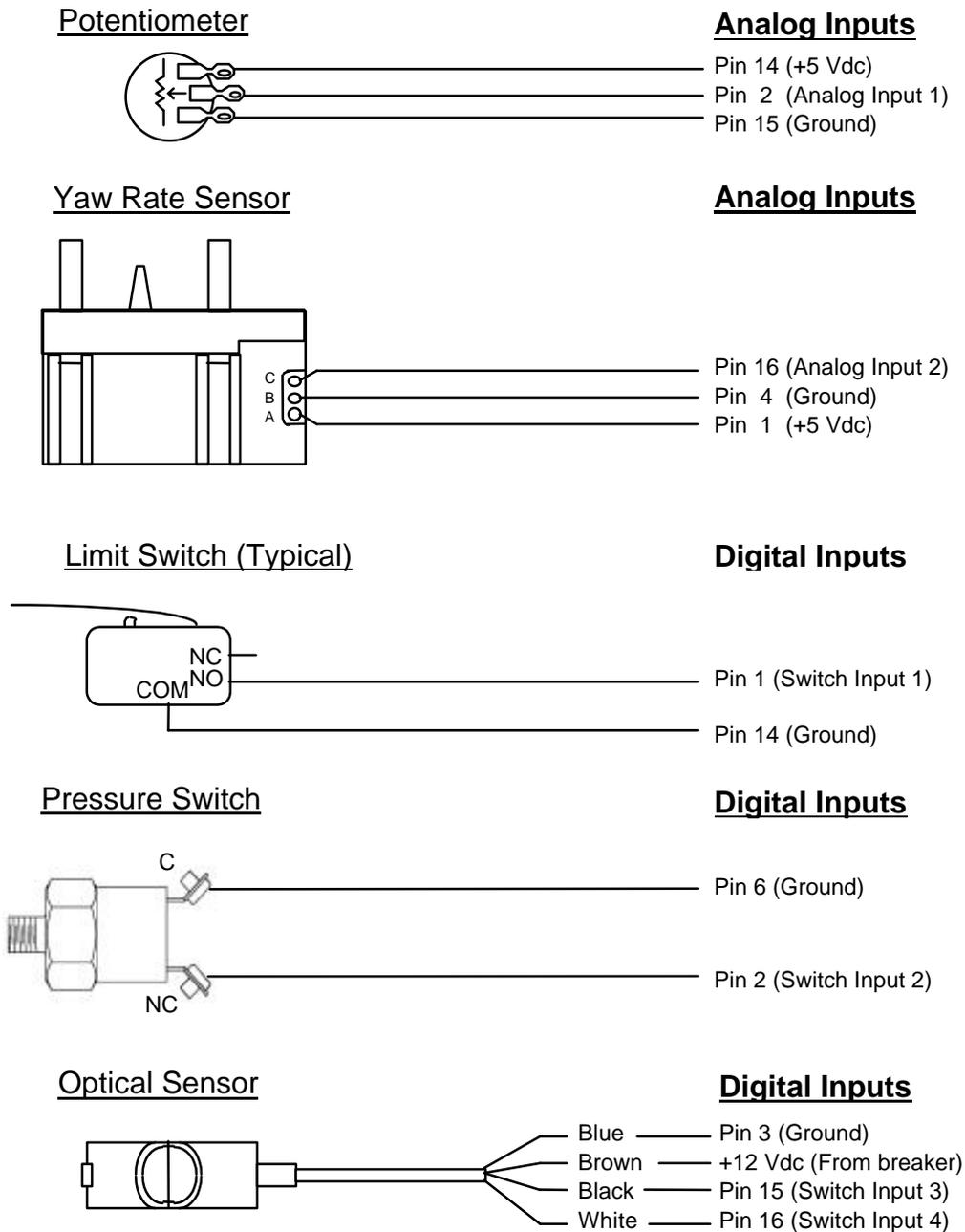


Figure 3.2: Connection Examples for Robot Controller

3.2.7 Custom Circuits and Additional Electronics

Teams may add additional electronics and custom circuits using allowed additional components. All additional electronics must draw power from a 20A circuit breaker.

- All outputs from the circuits must be connected to the sensor inputs on the Robot Controller. Inputs to the circuits may be connected to the following sources:
- 20A 30A or 40A circuit breaker outputs;
- Speed Controller or Relay module outputs;
- PWM or Relay outputs on Robot Controller;

- Switches, Potentiometers, the Yaw Rate Sensor, Optical Sensors, Motors and other allowed devices.

Custom Circuits may not:

- Interfere with the operation of other robots;
- Directly affect any output devices on the robot, such as by providing power directly to a motor, supplying a PWM signal to a speed controller or supplying a control signal to the relay module. (High impedance voltages monitoring inputs or low impedance current monitoring inputs on the custom circuits connected to the robot outputs are acceptable, because the effect on the robot outputs should be inconsequential.);
- Be used for wireless communication, such as sending or receiving a signal to and/or from the alliance station;
- Connect to the programming, radio or tether ports on the robot controller.

It will be impossible for FIRST to test all custom circuits, so we are relying on all teams to use Gracious Professionalism when using custom circuits.

Teams assume all responsibility for failures or unexpected behavior related to additional electronics and/or custom circuits. Please read the control system documentation from Innovation First for information on the robot controller sensor inputs. Support by FIRST and Innovation First for the additional electronics and custom circuits is limited to documentation provided in your kit and on the Innovation First web site.

3.3 Wiring the Operator Controls

3.3.1 Power Distribution

Power may be supplied to the Operator Interface in 3 different ways.

1. The A/C Adaptor power supply for the Operator Interface can be plugged into the power jack.
2. The Robot Controller will provide power to the Operator Interface when the units are connected together by the tether cable. This disables the radio modems, but is useful in situations where no AC power is available for the power supply.
3. During competition matches, a cable that plugs into the Competition port will supply power for the Operator Interface.

Due to the low current used by all the devices that connect to the Operator Interface, 24 AWG or larger wire is sufficient for all Operator Interface wiring.

3.3.2 Sensor Inputs on the Operator Interface

The exact wiring configuration for the joysticks, switches, potentiometers, LEDs, and the yaw rate sensor connected to the Operator Interface is not specified. Teams may wire these devices, within the rules as described below and according to the documentation supplied by Innovation First, in order to create a custom interface for the robot operators.

Although not a requirement, it is suggested that teams use a project box as a housing for the switches, potentiometers, LEDs, and yaw rate sensor. When using a project box, wire all components to the 15-pin male connector(s), mount the connector(s) on the project box, and use the 15-pin molded cable(s) to make the connection(s) to the Operator Interface.

The +12 Vdc LEDs may be connected between +5Vdc and Ground or between an LED output and Ground to serve as a visual indicator to the robot operators. This can be helpful during a competition match when a robot operator may not have a good view of the Operator Interface.

CAUTIONS

Connect switches between a switch input and Ground. *Do not use lighted switches with the Operator Interface unless the light is disabled.*

WARNING!

Do not connect switches to the +5Vdc fused Aux Pin (Pin 1) of the Input Ports of the Operator Interface. It may damage the switches. Pin 1 is intended to supply fused 5Vdc power for use by the Yaw Rate Sensor and Potentiometers.

The yaw rate sensor must be connected to +5 Vdc, Ground, and an analog input. Potentiometers must be connected to +5 Vdc and an analog input. Due to the special nature of the analog inputs on the Operator Interface, connecting potentiometers to Ground is optional but *not* required. See the Innovation First documentation for more information.

Figure 3.3 shows an example of the proper way to connect a switch, potentiometer, LED, and yaw rate sensor to the **Operator Interface**. Port and Pin designations shown in Figure 3.3 are examples and will vary depending on the number of devices connected.

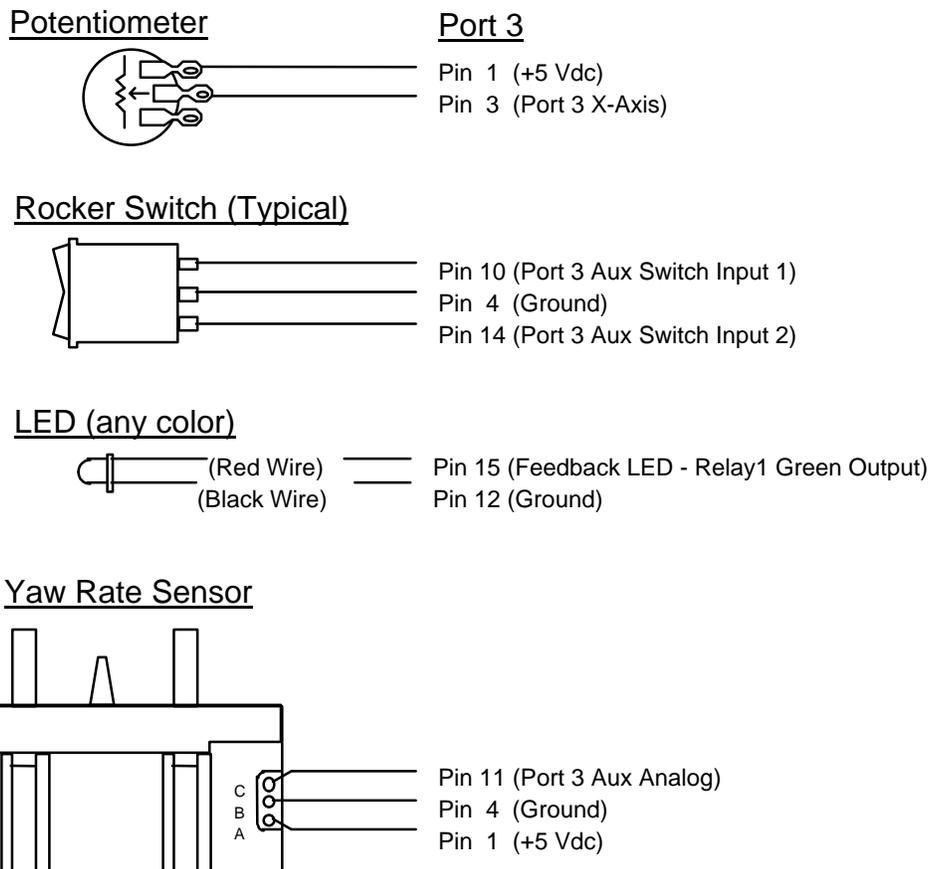


Figure 3.3: Connection Examples for Operator Interface

3.3.3 Dashboard Port

Teams are permitted to connect a portable computing device (Laptop computer, PDAs, etc.) to the RS232 Output of the Dashboard Port of the Operator Interface for the purpose of displaying feedback from the robot while competing in FIRST Robotics Competition matches. Portable computing devices *may not* be connected to inputs on the Operator Interface. Please note that *AC power will not be available at the playing field so these devices will have to run on internal batteries.*

Innovation First offers pre-written software for use in a Dashboard on their web site. Teams assume all risk associated with use of this program and/or data collected from the Dashboard port. For more information, consult the Innovation First web site at:

www.innovationfirst.com/firstrobotics

4 ROBOT RULES

The rules governing robot construction are divided into three sections **M**, **C** and **K**. See the table below for an explanation of the labeling.

<u>Section</u>	<u>Prefix</u>	<u>Rules Designation</u>
4.1	M	Machine Design & Operation Rules
4.2	C	Control System
4.3	K	Kit Materials Usage and Limitations

4.1 Machine Design & Operation Rules [M]

- M1** All custom parts and assembled mechanisms on the robot must be fabricated and/or assembled by the 2003 team after the start of the Kick-off. Mechanisms may not be reused from previous year's robots. Individual off-the-shelf components from previous year's robots may be re-used to save the cost of re-purchase of these parts.
- M2** You must design your Robot to be operated by the wireless, programmable Innovations First, Inc. Control System.
- M3** All robots will be inspected, weighed, and measured during the practice day at each FIRST Robotics Competition event. Robots may be re-inspected at anytime during an event at the discretion of FIRST.

The robot must pass inspection before competing in any qualifying competition matches, however, it is allowed to participate in practice rounds before passing inspection.

- M4** If a team wishes to have its robot re-inspected to ensure rules compliance, such as after making a modification to improve performance or reliability, the team may ask FIRST officials to do so. If you suspect that another team's robot is in violation of the robot rules, please approach FIRST officials and we will review the robot in question. This is an area where "Gracious Professionalism" is very important.
- M5** At the time of robot inspection, you must present *all* mechanisms that you will use on the robot during the entire competition event. It is acceptable, however, for a robot to play matches with a **subset** of the mechanisms that were present during inspection. Only mechanisms that were present during the inspection may be added, removed or reconfigured between matches. If subsets of mechanisms are changed between matches, the robot must still meet all inspection criteria. Robots must satisfy Rule M6 at all times.
- M6** All robots will be inspected for size and weight compliance and must:
- Fit, self-supported, within a 36" (91.44 cm) long x 30" (76.20 cm) wide x 60" (152.4 cm) space.

Self supported means that the robot and its parts (arms, subset mechanisms etc.) do not depend on the sizing box walls for support, i.e., if the robot were not in the sizing box, it would still fit within a volume that is the same size as the inside of the sizing box.

- Weigh no more than 130.0 pounds (58.97 kg). Weight limit includes battery, control system, decorations, bumpers and any other attached parts.

TIP: Keep in mind that these are absolute maximum weights and dimensions. We recommend that you design your robot with slightly smaller weights and dimensions. Check the size and weight of your robot during construction and before shipping it to a competition. Many teams have discovered the hard way that reducing size and/or weight to meet maximum requirements, while still preserving functionality, is no easy task after the robot has been fully constructed. Also, many shippers such as UPS and Fed Ex will not ship packages as large as a full robot. Many teams have found it helpful to make ease of disassembly and reassembly one of their design goals.

M7 *Robots must display their team number, sponsor and school names and/or logos. The judges, referees, and announcers must be able to easily identify robots by Team Number. Teams must display their Team Number in four locations at approximately 90-degree intervals around the side of the robot. **The numerals must be at least 4 inches high, at least in ½ inch stroke width and in a contrasting color from its background.** Team Numbers must be clearly visible from a distance of not less than 100 feet.*

TIP: Recognizable Team Identification is very important so that judges can give proper credit for exceptional performance and unique design features exhibited during competition matches.

M8 Robots must use the rotating light provided in the kit to display their alliance color (red or blue). The light must be mounted *upright* on the robot so that the color is always visible from a distance of at least 100 feet. The light should be mounted to allow easy changeover of the colored lens before matches. *See Section 3.2.2 for Rotating Light wiring information, also see Rule C26.*

M9 Teams may add “Non-functional” decorations to robots under the following conditions:

- Decorations must not cause the robot weight or size to exceed requirements of Robot Rules **Section 4.1, M6.**
- Decorations must not affect the outcome of the match.
- Any decorations that involve broadcasting a signal to/from the robot, such as remote cameras, must be cleared with FIRST prior to use. **900 MHz camera systems may not be used.**
- Decorations may draw power from the control system as long as they are powered via a dedicated 20A or 30A circuit breaker and do not affect the operation of other control system components.
- Decorations **must** be on your robot at the time of final inspection.
- Decorations **must** be in the spirit of “Gracious Professionalism”.

M10 Once a match begins, robots may extend beyond the starting size under their own power. Any restraints (elastics bands, springs, etc.) that are used to maintain starting size must remain attached to the robot for the duration of the match.

- M11** Energy used by FIRST Robotics Competition robots, i.e., stored at the start of a match, must come solely from:
- Electrical energy derived from the onboard 12Vdc battery;
 - Storage achieved by deformation of springs or latex tubing; no more than 20 ft-lbs (27.116 newton-meters aka joules) energy total stored at the start of a match;
 - Compressed air stored in the pneumatic system, but only supplied by the Pump included in the kit and stored at a maximum pressure of 120 PSI;
 - A change in the altitude of the device's center of gravity.
- M12** **Only** items listed under the PNEUMATICS section of the Kit list may be used to store, generate or transmit compressed air or vacuum, with the following exceptions:
- Suction cups may be fabricated from legal Kit parts, as defined in rule K1 below.
 - Tubing may be compressed in order to block the flow of air.
 - Tubing may not be compressed in order to generate compressed air or vacuum.
 - Only the allowed air cylinders may be used to generate vacuum.

WARNING!

You may only use pneumatic components from the pneumatics kit. Custom-made pneumatic components (fittings, air cylinders, pumps, valves, etc) are not allowed. Additional off-the-shelf pneumatic components are not allowed.

- M13** Teams are expected to design and build robots to withstand vigorous interaction with other robots. See Rule GM27 in The Game section of the manual.
- M14** In order to help reduce the impact forces that the robot will experience during collisions with other robots, teams may add external “bumpers” to the robot. If used, bumpers must satisfy the following constraints:
- Bumpers may extend outside the normal robot starting dimensions as follows:
 - Bumpers may extend out (in the horizontal plane) from the 30”x36” robot base up to 4”.
 - Bumpers must be located in a region from 2” to 8” above the playing field.
 - Bumpers must not cause the weight of the robot to exceed the weight limit.
 - Bumpers must be removable in order to allow the robot starting size to be easily measured during robot inspection.
 - Bumpers must remain attached to the robot for the duration of the match.
 - Rule K1 does not restrict materials used for bumper construction. Instead, the following restrictions apply:
 - Bumpers and any bumper mounts that extend beyond the regular robot starting size *may not contain “hard” materials* such as metal, wood, or hard plastics. The definition of “hard” is one of common sense, i.e., if you can punch it and not hurt your hand, it is ok.
 - Adhesive tape may not be used to fasten bumpers.

TIP: An example of an acceptable bumper design is a series of foam rubber tubes held in place by Velcro straps around the perimeter of the robot.

M15 The motors in the kit may **not** be modified except as follows:

- It is acceptable to modify the mounting brackets and/or other structural parts of the motors (output shaft, housing, etc.) as long as the electrical system is not modified and the integral mechanical system of the moving parts (bearings, bushings, worm gear output stages, etc.) is not changed or removed.
- The gearboxes for the Fisher-Price, Drill, and Globe motors are not considered “integral” and may be separated from the motors. FIRST will not provide replacement for parts that fail due to modification.

M16 Pneumatic components supplied in the Kit (pump, regulators, pressure switches, cylinders, valves, fittings, tubing, etc.) may not be modified except as follows:

- Tubing may be cut.
- The wiring for the valves and pressure switch may be modified as necessary to interface with the rest of the control system.
- Mounting and connecting pneumatics components using the pre-existing threads, mounting brackets, etc., is not considered a modification of the components.

M17 Robot wheels, tracks and other parts intended to provide traction on the playing field (“traction devices”) may be purchased or fabricated. In no case, will traction devices that damage the carpet or other playing surfaces be permitted. Traction devices may not have surface features such as metal or hard plastic studs, cleats or other attachments. The outer surface of off-the-shelf wheels may be modified by removing tread material only. In no case may a traction device protrude beyond the bottom surface of the Ramp mesh.

Gaining traction by using adhesives or Velcro-like fasteners material is not allowed.

M18 Mechanisms or components that present an obvious risk of entanglement are not allowed.

4.2 Control System Rules [C]

C1 The control system is provided to allow wireless control of the robots. The Operator Interface, Robot Controller, Servos, Speed Controllers, Relay Modules, Radio Modems, Batteries, Battery Charger, Power Supply, 9-pin cables, circuit breakers, fuses, and joysticks may not be tampered with, modified or adjusted in any way, with the following exceptions:

- The dip switches on the Operator Interface and Robot Controller may be set as appropriate.
- The program select jumper on the Robot Controller may be set as appropriate.
- The user programmable code in the Robot Controller may be customized.
- The Speed Controllers may be calibrated as described in owner's manuals.

Tampering includes drilling, cutting, machining, gluing, rewiring, etc. All items listed in Rule C1 must be mounted without alteration.

- C2** The Radio Modem connected to the Operator Interface must be able to reach the mounting bracket on the operator stations. Be sure to leave at least 36" of slack in the 9-pin cable.
- C3** The wire supplied in the Kit is to be used to conduct electricity. The chassis of the robot is *not* be used to conduct electricity. You may use additional wire as long as it meets the gauge and insulation color requirements as described in *Section 3*.
- C4** Electrical devices may only be wired as described in *Section 3*.
- C5** *You must use 6 AWG wire* to connect the battery to the 120A main circuit breaker/disconnect switch and to connect the 120A main circuit breaker/ disconnect switch to the fuse panels.
- C6** *You must use 10 AWG or larger* diameter wire for connections to and from the Speed Controllers if they are used with the Drill, CIM, Fisher-Price, Globe or Van Door motors. Even though the wires that are factory attached to these motors may be of a smaller size, the connection from the motor wires to the speed controllers must be as stated above.
- C7** *You must use 16 AWG or larger* diameter wire to connect the window motors to the Speed Controllers. You must also use 16 AWG or larger diameter wire from the Circuit Breaker Panels to the Robot, large muffin fan, and any other connections to and from the Relay Modules. The only exceptions are that 24 AWG wire may be used to connect the small muffin fans and any LEDs to the outputs of a Relay Module.
- C8** *You must use 24 AWG or larger* diameter wire for connecting sensors (switches, potentiometers, yaw rate sensor, optical sensors) to inputs, for extending the PWM cables, for the small muffin fans, or for wiring the LEDs. It is acceptable to use ribbon cable smaller than 24 AWG and not necessarily color-coded, to connect the 9 pin and 25 pin parts on the robot controller.
- If using ribbon cable, please take care to protect it from physical abuse (straining, pinching, or sharp bending) or failure of the internal wires is likely.
- C9** The additional electronics must be wired in accordance with the overall current draw of the complete circuit in which they are used.
- C10** A Relay Module may power no more than one motor or one pump. *Section 3.2.3 states* details of acceptable Relay Module output configurations.
- C11** The Robot Controller, Relay Modules, 12Vdc LEDs, additional electronics, and muffin fans may be connected directly to 20A circuit breaker outputs. The Speed Controllers for the Globe motors, Fisher-Price motors, and the Van Door motor may be connected to 30A or 20A circuit breaker outputs. Only the Speed Controllers for the Drill motors and CIM motors may be connected to the 40A Maxi Breaker Block outputs.
- C12** The Drill motors, Fisher-Price motors, Globe motors, CIM motors, and Van Door motors may only be powered by the Speed Controllers. Do not connect these motors to the Relay Modules.
- C13** No more than one drill motor, Fisher-Price motor, Globe motor or Van Door motor may be powered by each Speed Controller. The pneumatic pump may be powered by a Speed Controller using a 20A or 30A breaker.
- C14** The Window motors, pump, and 12Vdc LEDs may be powered by the Speed Controllers or the Relay Modules. Optionally, one Speed Controller may power two window motors.

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- C15** All circuit breakers must be accessible for inspection at each FIRST Robotics Competition event.
- C16** You must install the 120A circuit breaker in series with the positive terminal of the battery such that all battery output flows through the breaker before being distributed to any electrical component on the robot. The breaker must be accessible for inspection at each FIRST Robotics Competition event.
- TIP:** The 120A circuit breaker is also the power switch for your robot. *Please make it safely accessible.*
- C17** Do not connect 12Vdc power, Relay Module outputs, Speed Controller outputs, or PWM outputs to the analog or switch inputs on the Robot Controller.
- C18** You must connect all outputs from the sensors and additional electronics circuits used on the robot directly to the analog or switch inputs on the Robot Controller. **Sensors may not be wired in series with the motors.** It is acceptable to wire switches in series or parallel with each other.
- C19** During each competition match, your robot may be powered by only one of the two batteries provided by FIRST.
- C20** When recharging Kit batteries, you may use the charger provided by FIRST or one with equivalent charging characteristics.
- C21** All wires distributing power with a constant polarity (i.e., not a Relay Module, Speed Controller or sensor output) must be color-coded as follows:
- Use Red or White wire for +12 Vdc and +5 Vdc connections.
 - Use Black wire for Common (-) connections.
- C22** Teams are responsible for any software bugs introduced into the Robot Controller's control program when using a custom program.
- C23** Teams are responsible for any unwanted or unanticipated robot behavior when using additional electronics.
- C24** The Robot Controller must be positioned within the robot so that its LED's may be seen during inspection and during operation in a match. This will greatly facilitate analysis in case of problems and will be beneficial to you and field personnel during the FIRST Robotics Competition.
- C25** The terminals on the battery must be insulated with electrical tape to reduce the risk of short circuits.
- C26** A Relay Module must power the rotating light provided in the kit such that it turns on when the robot is enabled, and turns off when the robot is disabled. The light must be mounted upright. *See Section 3.2.2 for details. Also, see Rule M8.*
- C27** The team number settings on the Robot Controller and Operator Interface must be set to the team number assigned to the team by FIRST.
- C28** Teams may not use Innovation First Operator Interfaces from previous years competitions.
- C29** The use of additional electronics is intended to allow teams to construct custom circuits for their robots. The custom circuits may be used to indirectly affect the robot outputs, by providing enhanced sensor feedback to the Robot Controller to allow it to more effectively decide how to control the robot outputs. The custom circuits must draw power from a 20A circuit breaker. Smaller value fuses may be

incorporated into the custom circuits for additional protection. All outputs from the custom circuits must be connected to the analog or digital sensor inputs on the Robot Controller.

Inputs to the circuits may be connected to the following sources:

- Circuit breaker outputs.
- Speed Controller or Relay module outputs.
- PWM or Relay outputs on Robot Controller.
- Switches, Potentiometers, the Yaw Rate Sensor, Optical Sensors, Motors and other additional electronics allowed in the restricted parts list.

Custom Circuits may not:

- Interfere with the operation of other robots
- Directly affect any output devices on the robot, such as by providing power directly to a motor, supplying a PWM signal to a speed controller or supplying a control signal to the relay module. (High impedance voltages monitoring inputs or low impedance current monitoring inputs on the custom circuits connected to the robot outputs are acceptable, because the effect on the robot outputs should be inconsequential.)
- Be used for wireless communication, such as sending or receiving a signal to and/or from the alliance station.
- Connect to the programming, radio or tether ports on the Robot Controller.

4.3 Materials Usage & Limitations Rules[K]

- K1** Each robot must be constructed from components provided in the Kit of Parts ("the Kit") supplied by FIRST, and from "additional components" that satisfy the requirements of the Restricted Parts List (see Rule K2). Some of the components in the Kit are raw materials intended for manufacturing structural or mechanical parts for your robot. Before purchasing new parts or fabricating additional parts, refer to the Part Use Flowchart (Figure 4.1) to determine if a part or material is permitted for use on your robot.
- K2** The Restricted Parts List must be reviewed when selecting "additional components" for use on the robot. If a part falls into one of the listed categories, then carefully review the items in the category to determine whether or not it is allowed. If a part category does not list the part you wish to use, then it is not allowed. If a part does not fall into any of the categories in the Restricted Parts List, then it is allowed. Additional components may be obtained from any supplier, unless otherwise specified.

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Examples:

Item	Status	Reason
Aluminum plate	Allowed	Does not fall into any categories so it is allowed
Additional valves	Not allowed	Falls under Pneumatics; not listed
Additional speed controllers (Victor 883, 884)	Allowed	Falls under Electronics; listed as allowed
Titanium plate	Not allowed	Falls under Exotic Materials; listed as quantity none

K3 The total cost of “additional components” used on the robot may not exceed \$ 3,500 USD. No individual component cost may exceed \$ 400 USD. The total cost of components purchased in bulk may exceed \$ 400 USD as long as the cost of each individual component does not exceed \$400. Non-functional decorations are exempt from the total cost calculation but bumpers are not exempt. The “cost” of each component is counted as follows:

- The purchase price of a component that you order off the shelf;
- The total cost (materials plus labor) of a component that you pay someone else to make;
- The fair market value if you buy a component at a discounted price or obtain it as a donation;

Ex.: The fair market value is the price at which a component is usually available, i.e., its typically advertised price. If you were to buy the same component from 10 different sources, what price is most representative of the 10 sources?

- The cost of the raw material if the component was custom fabricated by the team (a team’s internal labor does not count towards the cost of the component);

Ex.: A team buys a 4’ x 4’ x 1” steel plate and cuts several gears from it using just team labor. The raw material cost counts but the labor does not.

- Shipping cost is not counted;

You may prorate the total cost of materials that you buy in bulk or in large quantities:

Ex.: You buy a box of 500 rivets but only use 100; the prorated cost is 1/5 of the cost of the bulk box;

Ex.: You buy a 25’ piece of aluminum angle and you use 10’; the prorated cost is 2/5 of the cost of the aluminum.

K4 Raw materials may be machined or fabricated into custom parts.

K5 Additional electronic components for use on the robot must be currently available from Future Active (www.future-active.com) or Digi-Key Corporation (www.digikey.com). The total catalogue value of additional electronic components must not exceed \$200.00 USD. This cost is counted as part of the \$ 3,500 limit per Rule K3. No single component shall have a catalog value of over \$100.00 USD.

K6 A list of all purchased materials, including costs, used in the construction of the robot shall made available if requested by FIRST. At each competition event, teams should be prepared to present a complete materials list/spreadsheet that details the source and cost of each additional component of the robot, if requested.

K7 Electrical tape is the only adhesive tape that may be used on the robot. It may only be used as an electrical insulator.

K8 Lubricants may be used only to reduce friction within the robot. Lubricants shall not be allowed to contaminate the playing field surfaces, containers or other robots.

K9 For safety reasons, you may not fabricate your own springs. However, it is acceptable to elastically deform and relax materials not designated as springs as long as the rate at which the energy is released does not exceed the rate at which the energy was stored. This is intended to allow reasonable use of the elastic properties of materials without creating unsafe conditions caused by the sudden release of stored energy in materials not designed to act as springs. Materials that are designated as springs include:

- All items listed in the Springs section of the Kit List;
- Springs currently available from **MSC Industrial Supply Co., Inc.** or **Small Parts Inc.**;
- Latex tubing.

Pneumatic actuators may not be modified or plugged in any way for use as a spring.

K10 If “springs” are used for launching the containers, only latex tubing that is the same as the tubing in the kit, i.e., 1/4” ID and 3/8” OD by 5 feet maximum in length may be used. See Rule S10 in the Game section of the Manual.

K11 Teams may replace lost or damaged Kit components only with identical components of the same material, dimensions, and treatment.

K12 Materials in the Kit may not be changed chemically with the following exceptions:

- Rope ends may be singed to prevent loose ends or to bind them together
- Metal may be heat treated
- Metal may be anodized to improve appearance

The melting and recasting of materials, such as a block of aluminum, is allowed as long as the basic alloy or chemical composition is not changed. Note, however, that other rules restrict which parts may and may not be modified. For example, the motors and pneumatic cylinders in the kit may not be melted and recast.

K13 The plastic Kit containers, part packaging, and any documentation in the Kit container may not be used as a component to build the robot or robot control system.

Part Use Flowchart

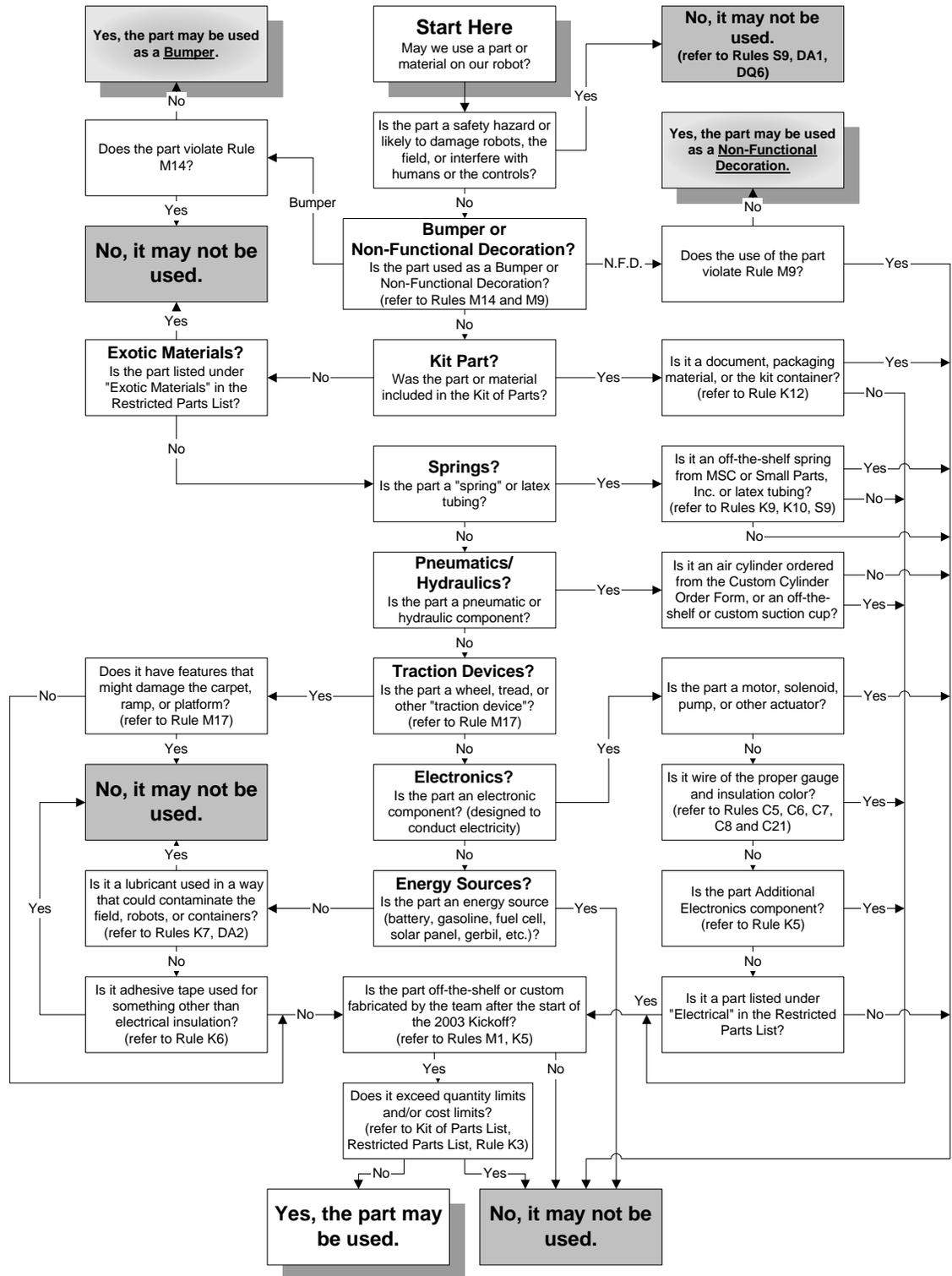


Figure 4.1 – Part Use Flowchart

5 KIT OF PARTS

Please check the FIRST web site and Team Updates for changes to the Kit of Parts list.

Kit of Parts

Bearings

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Flange, Two Bolt Self-Aligning, 40MST	Fits 1/2" Bearing	8	The Torrington Company
Radial Ball Bearing, S7KDD, with Shields	5/8" I.D. - 1.375 OD - .344 Width	12	The Torrington Company
Radial Ball Bearing With Spherical O.D., RA008RRB	1/2" I.D., Self Locking Collar	4	The Torrington Company

Control System

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Optical Sensor		3	Banner Engineering Corporation
Yaw Rate Sensor		1	BEI Systron Donner Inertial Division
Connector for Yaw Rate Sensor	3 pin, 24 AWG x 12" cable	1	Delphi Packard Electric Systems
15-Pin Molded Cable	DB15 pin M-M, 6 feet	2	Innovation First, Inc
9-Pin Cable	DB9 Male to Female, 6', Shielded	4	Innovation First, Inc
Flightstick Joystick	7" Cable with Male DB15	2	Innovation First, Inc
Operator Interface		1	Innovation First, Inc
Power Supply for Operator Interface	9 Vdc	1	Innovation First, Inc

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Kit of Parts

PWM/Relay Cable	Hitec/JR-style, 36" Long	8	Innovation First, Inc
PWM/Relay Y Cable	Hitec/JR-style, 24" Long	2	Innovation First, Inc
Radio Modem for Operator Interface	RS-422, 9 pin F, metal antenna	1	Innovation First, Inc
Radio Modem for Robot Controller	RS-422, 9 pin F, rubber antenna	1	Innovation First, Inc
Relay Module (Spike)	12V, 20A Max	4	Innovation First, Inc
Robot Controller		1	Innovation First, Inc
Servo	42 oz./in. peak torque, 0.19 sec./60°	2	Innovation First, Inc
Speed Controller (Victor 884)		4	Innovation First, Inc
15-Pin Solder Cup Connector	DB15 Female	2	TYCO Electronics Foundation
25-Pin Solder Cup Connector	DB25 Male	2	TYCO Electronics Foundation
Plastic Shield for 25-Pin Connector	fits DB25 Connector	2	TYCO Electronics Foundation

Documentation

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Anderson Power Products Catalog	Catalog	1	Anderson Power Products

Kit of Parts

FedEx Airbills		3	FedEx
FedEx Envelope - Introduction Letter		1	FedEx
Manual - 2003 FIRST Robotics Competition		1	FIRST
Video, Compilation of Past Competitions	Video	1	FIRST
McNichols, Catalog, Stickers, Rulers	Catalog and trinkets	1	McNichols Company
Magazine, Nut and Volts		1	Nuts and Volts

Electrical

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Quick-Disconnect Power Connector (with 1' leads)	#6 AWG Red/Black Wire, pair	2	Anderson Power Products
1 Conductor Wire	35', #10 AWG, Red	1	BICC General
1 Conductor Wire	35', #10 AWG, Black	1	BICC General
2 Conductor Jacketed Wire	35', #16 AWG	1	BICC General
2 Conductor Jacketed Wire	30', #24 AWG	1	BICC General
3 Conductor Shielded Wire	30', #24 AWG	1	BICC General

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Kit of Parts

3 Conductor Shielded Wire	20', #24 AWG	1	BICC General
LED, Panel Mount	Green, 12V	2	Chicago Miniature Lamp, Inc.
1 Conductor Wire	10', #6 AWG, Black	1	Delphi Connection Systems
1 Conductor Wire	10', #6 AWG, Red	1	Delphi Connection Systems
Maxi Block, Base, 1 of 4 pieces	Use maxi-style circuit breakers only; base, insert, fuse block, bolt	1	Delphi Connection Systems
Maxi Block, Fuse Block, 8 Position; With 4 Wires; 1 of 4 pieces	Use maxi-style circuit breakers only; base, insert, fuse block, bolt	1	Delphi Connection Systems
Maxi Block, Insert, 8 Position, 1 of 4 pieces	Use maxi-style circuit breakers only; base, insert, fuse block, bolt	1	Delphi Connection Systems
Muffin Fan (Large)	12 Vdc	1	EBM Industries
Muffin Fan (Tiny)	12 Vdc	5	EBM Industries
Battery	12 volt, 18 AH Deep Cycle Non-Spillable	2	Exide Technologies
Maxi Block, Bolt, 20mm Flanged, With Yellow Zinc Plating, 1 of 4 pieces	Use maxi-style circuit breakers only; base, insert, fuse block, bolt; 20mm flanged, with yellow zinc plating	1	Fastenal
Helical Plastic Wire Wrap	1/4" Ø x 24"	1	Hellermann Tyton
Helical Plastic Wire Wrap	1/2" Ø x 24"	1	Hellermann Tyton

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Kit of Parts

Breaker, Buss, Ckt Breaker / Disconnect Switch	120A., automotive style	1	Innovation First, Inc
Breaker Panel	ATC, 100A. max	2	Innovation First, Inc
Snap-Action Circuit Breaker	30 amp, 12 volt, Auto-Resetting	7	Innovation First, Inc
Snap-Action Circuit Breaker	20 amp, 12 volt, Auto-Resetting	5	Innovation First, Inc
Snap-Action Circuit Breaker	40 amp, 12 volt, Auto-Resetting	4	Innovation First, INC
Revolving Light, Taiwan	with red and blue lenses	1	Juluen Enterprise Co., Ltd (Taiwan)
Battery Charger, Automatic	6A.	1	Midtronics (Exide spinoff)

Fasteners

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Velcro grip tie (2 in a pack)	6"x 1"	1	Hellermann Tyton
Velcro Grip Ties	8" x 1.75"	2	Hellermann Tyton
Velcro 18" One Wrap grip tie	1"x18" grip tie White	2	Velcro USA, Inc.

Field Components

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Ramp Surface Material, Kit Sample, 12" x 18"	Carbon steel wire cloth, 1" mesh, .118 wire diameter	1	McNichols Co.

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Kit of Parts

High-Density Polyethylene (HDPE)	6" x 6" x 1/4" kit sample; this is thinner than the platform material but is to demonstrate the surface	1	Plastic Supply
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Motors & Pumps

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Screw, Left-Hand for Bosch 1/2" Drill Drive Assembly		2	ADM Tool
(MM) Spacer, Steel	Spacer for 2" x 4" material; 0.277 ID; 0.375 OD; 1.75" long	4	AM Industries
Motor, Van Door, Bosch	12 Vdc, 75 RPM	1	Bosch Automotive
Motor, CIM (aka Chiaphua or Atwood), 8mm keyed output shaft	8mm keyed output shaft	2	CCL Industrial Motor, LTD
Coupler to Nippon-Denso Motor Gear	Injection molded	2	DEKA
Nippon-Denso Motor, Window, Right		2	Denso International America, Inc.
(MM), Bolt, Motor Mount, 1/4-20 x 1"; 307AHB 1/4-20 x 1Z	Bolt	1	Fastenal
(MM), Bolt, Motor Mount, 1/4-20 x 2.5"; 307AHB 1/4-20 x 2-1/2Z	Bolt	1	Fastenal
(MM), Bolt, Motor Mount, 10-32 x 2"; SHCS 10-32 x 2	Bolt	1	Fastenal
(MM), Nut, Motor Mount, 1/4-20; NYLOCK NE 1/4-20Z	Nuts	1	Fastenal
(MM), Nut, Motor Mount, 10-32; NYLOCK NM 10-32Z	Nuts	1	Fastenal

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(MM), Washer, Motor Mount, 1/4-20; SAE F/W 1/4Z	Washers; washer under bolt head and nut	1	Fastenal
(MM), Washer, Motor Mount, 10-32; SAE F/W (#10) Z	Washers; washer under bolt head and nut	1	Fastenal
Fisher-Price 10 Web Jeep Driver	Black	2	Fisher-Price, Inc.
Motor/Gearbox, Fisher-Price	12 Vdc stall torque (mNm) 532.19+/- 10% 21T #7 Gearbox	2	Fisher-Price, Inc.
Motor, Globe, with Drive Assembly	12Vdc	2	Globe Motors
Mount for 1/2" Drill Motor	Injection molded	2	NYPRO, Inc
Drill Drive Assembly (Transmission), 1/2"	2 Speed -12.07:1 & 42.62:1 Gear Ratios	2	S-B Power Tool
Motor Assembly, 1/2"	0.87Nm @ 127A stall, 19670RPM No-Load	2	S-B power Tool Co.

Other

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Reflexite, retroreflective, 1" wide x 6" long	This was bought in 2002 and we have enough for 2003	1	Reflexite

Pneumatics

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Pneumatics Kit, 0-160psi Gauge for Norgren Regulator, Norgren		3	Various
Pneumatics Kit, 1/4" OD Tubing, SMC	20 meters	1	Various

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Pneumatics Kit, Adaptor 1/4" Female to 1/8" Male, Parker		6	Various
Pneumatics Kit, Bushing 1/8" Female to 1/4" Male, Parker		12	Various
Pneumatics Kit, Compressor, Thomas		1	Various
Pneumatics Kit, Cylinder, Parker	1.5" bore x 8" stroke; rear pivot mount	1	Various
Pneumatics Kit, Double Solenoid Base Ported Valve, SMC		2	Various
Pneumatics Kit, Fitting, 90 Elbow 1/4" Tube, SMC		20	Various
Pneumatics Kit, Fitting, Male Run T 1/8 NPT ~ 1/4" Tube, SMC		5	Various
Pneumatics Kit, Fitting, Straight 1/4" Tube, SMC		20	Various
Pneumatics Kit, Fitting, Tee Union 1/4" Tube, SMC		5	Various
Pneumatics Kit, Flow Control, SMC		6	Various
Pneumatics Kit, Hex Nipple 1/8" NPT, Parker		6	Various
Pneumatics Kit, Main Regulator with 60psi Max Output, Norgren		1	Various
Pneumatics Kit, Manual 2-Way Plug Valve, Parker		1	Various

Kit of Parts

Pneumatics Kit, Pivot Bracket Set, Cylinder, Parker		1	Various
Pneumatics Kit, Plug 1/4", Parker		6	Various
Pneumatics Kit, Plug 1/8", Parker		6	Various
Pneumatics Kit, Pressure Switch Opens @ 115psi; Closes @ 95psi, Nason		1	Various
Pneumatics Kit, Regulator Mounting Bracket and Nut, Monnier		1	Various
Pneumatics Kit, Regulator Mounting Bracket and Nut, Norgren		1	Various
Pneumatics Kit, Relief Valve, 120psi, Norgren	120psi	1	Various
Pneumatics Kit, Rod Clevis, Cylinder, Parker		1	Various
Pneumatics Kit, Secondary Pneumatic Regulator, Monnier		1	Various
Pneumatics Kit, Teflon Tape, 1/4" x 100'		1	Various
Pneumatics Kit, Union Tee, Parker		4	Various
Pneumatics Kit, Valve Kit, Solenoid, With Fittings, Festo		1	Various
Pneumatics Kit, Vibration Isolators for Compressor, Lord Corp		1	Various

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Pneumatics Kit, Volume Tank, Clippard	16 cu. in., 2" x 8"	2	Various
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Rods & Shafts

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
(GB) Spacer, Steel	Spacer for 2" x 4" material; 0.277 ID; 0.375 OD; 1.75" long	8	AM Industries
Gear, 1" Helical, 5/8" Keyed Bore, Right Hand		2	Boston Gear
Gear, 2" Helical, 5/8" Keyed Bore, Right Hand		2	Boston Gear
Key Stock, Metric	Metric key stock; fits the shaft on the Chiaphua motor only; 0.079" x 0.094" x 1"	2	CCL Industrial (Chiaphua)
Coupling, 1/2" Drill Motor, Aluminum, accepts 1/2" Drill Shaft, 1" Hex OD	Fabricated for FIRST; aluminum; part of a 3-piece assembly for 1/2" Skil-Bosch	2	ComTech
Coupling, 1/2" Drill Motor, Aluminum, accepts 5/8" Keyed Shaft, 1" Hex OD	Fabricated for FIRST; aluminum; part of a 3-piece assembly for 1/2" Skil-Bosch	2	ComTech
Coupling, Aluminum, accepts 8mm Chiaphua Shaft, 1" Hex OD	Fabricated for FIRST; aluminum; part of a 3-piece assembly for 8mm Chiaphua shaft	2	ComTech
Pillow Block	Manufactured for FIRST, aluminum, accepts bearing for 5/8" shaft	4	ComTech
Coupling, Plastic, Round, 1/2" Skil-Bosch, Accepts 1" Hex Both Sides	Fabricated for FIRST; plastic; part of a 3-piece assembly for 1/2" Skil-Bosch	2	DEKA
Coupling, Plastic, Round, Chiaphua, Accepts 1" Hex Both Sides	Fabricated for FIRST; plastic; part of a 3-piece assembly for 8mm Chiaphua shaft	2	DEKA
Flexible Shaft Coupling	Black	2	DEKA

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Kit of Parts

Worm Gear Actuator-Left Hand	2 inch linear movement	1	Excellence Manufacturing, Inc.
Worm Gear Actuator-Right Hand	2 inch linear movement	1	Excellence Manufacturing, Inc.
(GB), Bolt, 307AHB 1/4-20 x 6.5Z, Hex Head	For gear box	1	Fastenal
(GB), Nut, NYLOCK NE 1/4-20Z	For gear box bolts	1	Fastenal
(GB), Washer, Belleville (Disc Spring)	1.250 x 0.630 x 0.0400; for preloading in the gear box; Gardiner Spring 800-331-3263; come in pkg of 12	5	Fastenal
(GB), Washer, Flat, 1/4" Hole, USS F/W 1/4Z	Washer for gearbox fastening bolts	1	Fastenal
Retaining Rings for 5/8" Keyed Shaft		1	Fastenal
Fisher-Price Axle	7/16" \varnothing x 26"	1	Fisher-Price, Inc.
Shaft, 5/8" Keyed	5/8" keyed x 36"	1	G & G
Flexible Motor Shaft	13.5" Long, Fits Seat Motor	2	Grand Rapids Controls
Key Stock, 3/16" x 12"	3/16" key stock; fits 5/8" shaft but not the 1" or 2" gears	1	ITW Bee Leitzke
Key Stock, Step, 1/8"+3/16" x 12"	1/8" and 3/16" step key stock; the 1/8" side fits the 1" and 2" gears; the 3/16" side fits the 5/8" shaft; 12" piece	1	ITW Bee Leitzke
Lead Screw w/ Nut	12" Long	1	Kerk Motion Products, Inc.

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Coupling, Aluminum, Solid, 1" Hex OD, 3" Long	Commercially available; aluminum; part of a 3-piece assembly for 8mm Chiaphua shaft	2	Northstar Steel and Aluminum, Inc
Shaft, DGP (drawn, ground, polished)	5/16" Ø x 18" TGP	1	Northstar Steel and Aluminum, Inc
Shaft, DGP (drawn, ground, polished)	1/2" Ø x 18" TGP	1	Northstar Steel and Aluminum, Inc.
(GB), Gearbox, Clamping Plate for 2" x 4" Frame (can be used on smaller stock)	Injection Molded	2	Nypro
(GB), Gearbox, Pillow Block Half	Injection Molded	8	Nypro
(GB), Gearbox, Pillow Block Mounting Plate, Used in Pairs	Injection Molded	4	Nypro
(GB), Spacer, Pipe, for Gear Box	0.652 ID; 0.75 OD; 0.049 wall x 24"; teams can cut it into lengths of their choice	1	Yarde Metals

Software

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
3D Studio Max 5, Autodesk	Includes Character Studio - see separate record	1	Autodesk
Animations from 2002 Season, Autodesk	1 DVD	1	Autodesk
Character Studio, Autodesk	Included with 3D Studio Max 5	1	Autodesk
Inventor Series 6, Autodesk	Includes Mechanical Desktop - see separate record	1	Autodesk
Manufacturing Education Curriculum 2002 for Autodesk 5.3 and Autodesk Streamline, Autodesk	1 CD	1	Autodesk

Kit of Parts

Mechanical Desktop, Autodesk	Included with Inventor Series 6	1	Autodesk
Training Booklet and CD, Inventor Series 6, Autodesk	1 CD	1	Autodesk
FileMaker Pro		1	FileMaker
Microsoft, Front Page		1	Microsoft
Microsoft, Project		1	Microsoft
Microsoft, Visual Studio Net		1	Microsoft

Springs

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Spring, Compression	Yellow	6	Associated Spring Raymond
Spring, Compression	Silver	6	Associated Spring Raymond
Spring, Compression	Blue	1	Associated Spring Raymond
Spring, Compression	Small Silver	8	Associated Spring Raymond
Spring, Compression	Small Brass	4	Associated Spring Raymond
Spring, Compression	Med. Brass	7	Associated Spring Raymond

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Spring, Compression	Med. silver	6	Associated Spring Raymond
Spring, Extension	Black	3	Associated Spring Raymond
Spring, Extension	Small Silver	6	Associated Spring Raymond
Latex Tubing	1/4" I.D., 3/8" O.D., 5'	2	Kent Elastomer

Structural

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
(TR) Spacer, Steel	Spacer for 2" x 4" material; 0.495 ID; 0.625 OD; 1.75" long	4	AM Industries
(TR), Nut, NYLOCK NE 3/8-16Z	3/8" nut for threaded rod	1	Fastenal
(TR), Washer, Flat, 3/8" Hole, USS F/W 3/8Z	Flat washer for 3/8" threaded rod	1	Fastenal
Frame, 2" x 4" Extruded Aluminum	2" x 4" x 36"	2	Hadco
Pipe, 1" Aluminum	1" x 24" schedule 40	2	Hadco
(TR), Threaded Rod , 3/8"	3/8" Ø x 36", 20 Pitch Coarse Thread	2	Northstar

Wheels

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Qty/Kit</u>	<u>Product Supplier</u>
Wheel, 9", Skyway	5/8" keyed hub	2	Skyway Recreation Products

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Wheel, Wheelchair, 6"	6" Ø, 5/16" I.D. Bearings, 1-1/2" Wide Flange	2	Skyway Recreation Products
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6 RESTRICTED PARTS LIST

Electronics	
Additional Electronic Components	Up to \$200 (U.S.) worth from Future FAI or Digi-Key. No individual part cost > \$100.
DB15 M-M Cable	6' Length, Up to 2
Diode for Double Solenoid Valves	P/N: 1N4001, 1A Max, up to 4
Insulated Electrical Connectors	Any amount/size, off-the-shelf, proper gauge/current rating
Joystick, Steering Wheel, or Pedals	15 pin (not USB) PC interface, up to 6
Optical Sensor	Banner Engineering part # QS18VN6LV, any quantity
Potentiometer	Any amount, 100k Ohms, linear taper
PWM/Relay Cable	Hitec/JR-style, 36" Long, Any Amount
PWM/Relay Y Cable	Hitec/JR-style, Any Amount
Relay Module (Spike)	Any amount - when used per rules
Snap-Action Circuit Breaker	30 amp, 12 volt, Auto-Resetting, Any Amount - when used with Speed Controller
Snap-Action Circuit Breaker	20 amp, 12 volt, Auto-Resetting, Any Amount
Speed Controller (Victor 883)	Any amount - when used with motor
Speed Controller (Victor 884)	Any amount - when used with motor
Switches	Any amount, off-the-shelf, non-powered
Terminal Blocks	Any amount, off-the-shelf, proper gauge/current rating
Wire	Proper gauge, color & insulated
Wire Nuts	Any amount
Energy Sources	
None	See Rule M11

Exotic Materials	
Beryllium	None allowed
Carbon-Fiber	None allowed
Ceramics not used as electrical insulators (Ceramics as insulators are ok)	None allowed
Semi-Precious Jewels	None allowed
Titanium	None allowed

Pneumatics/Hydraulics	
Air Cylinder	From Custom Cylinder Order Form, up to 3
Suction Cup	Off-the-shelf or custom, any manufacturer, any quantity, any size

Springs	
Latex Tubing used as a spring (latex tubing not used as a spring is not restricted)	Off-the-shelf, any manufacturer, any quantity, 1/4" ID x 3/8" OD, see Rule S9 in the Game section
Springs	Off-the-shelf from MSC or Small Parts, any quantity, any size, see Rule S9 in the Game section

Traction Devices	
Belts used as treads (belts not used as treads are not "traction devices")	Any manufacturer, any quantity, any size, see Rule M17
Wheels	Any manufacturer, any quantity, any size, see Rule M17

7 FIRST POLICY ON REPLACEMENT OF KIT PARTS

7.1 Design and Build Phase

FIRST has only a limited supply of replacement parts available.

If, during examination of returned failed components, the failure is determined to be due to misuse of parts or incorrect wiring, in general, only one (1) additional replacement unit will be supplied by FIRST.

FIRST will not provide replacement for parts that because of Team modification.

You must provide your Team number and daytime contact information when returning any broken part to FIRST for replacement.

- Unless otherwise specified, replacement parts shipped from FIRST will ship via 2nd day air within one business day of receipt of the non-functional part. Teams may opt for overnight shipment at their expense by requesting it and providing their shipping company preference and account number (UPS, FedEx, etc.). *FIRST will not accept credit cards.*
- FIRST does not provide “back up” spare parts to teams. When possible, FIRST will provide teams with information on whom to contact to obtain extra kit parts. However, due to the nature of how the Kit of Parts is assembled, there will be some kit items for which spares are simply not available. Teams wishing to obtain extra parts for use in robot development or to have on hand as backup, should utilize regular retail channels or consult the Kit of Parts suppliers. Supplier Contact Information will be furnished at a later date. *If the address for a supplier is not given, then that supplier is not prepared to supply parts directly to teams. Do not contact parts suppliers if they are not listed in the supplier contact information.*

7.2 FIRST Replacement Policy for Kit Parts at Events

Some kit parts are no longer available as spares at the events. Many kit parts are donated in bulk quantities sufficient to stock the Kit of Parts. Maintaining and transporting an inventory of a complete supply of spare parts has become unmanageable. This is due to the continued increase in the number of teams, events, and the difficulty of obtaining extra parts.

No more than two of each type of motor provided in the Kit of Parts will be given to any team at any event as a replacement. Please remember to use “Gracious Professionalism” when requesting new motors. FIRST does not have enough stock to provide for all teams at every event.

7.3 FIRST Loan Policy for Control System Components

Teams are responsible for all Innovation First products required at events. If, at any event, a team needs to borrow any part of the Control System, the team must provide a Credit Card number to ensure proper return of the items after the completion of the event.

If the part is not returned at the end of the event, FIRST retains the right to bill the provided credit card number for the borrowed items.

All “loan” items are available on a first-come, first-served basis.

7.4 Innovation First Products

The following kit parts are Innovation First products:

- Operator Interface
- Robot Controller
- Radio Modems
- AC Adapter for Operator Interface
- Speed Controllers (Victor 883, Victor 884)
- Relay Modules (Spike)
- PWM/relay cables
- 9-pin cables
- 15-pin cables

Do not contact FIRST for repair or replacement of these Control System items as they are covered by a product warranty from Innovation First. Please visit the Innovation First web site for product support or to obtain a Return Merchandise Authorization Number (RMA#) to return Control System components for replacement.

Contact Innovation First at:

www.innovationfirst.com/firstrobotics/

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8 SAMPLE – 2003 INSPECTION SHEET

2003 FIRST Robotics Competition **SAMPLE** Inspection Check List

Team #			PASS	
Weight	_____	Heaviest configuration with battery, bumpers, and decorations (£130.0)	Initials	
Size	_____	Must fit freely in ready-to-run condition with no bumpers (30"x36"x60")	DATE	
C.C Cost	_____	Custom circuit board (U.S. \$)	TIME	
MECHANICAL				
	Team name and/or logo and number on 2 sides - 5" numerals 180 deg. apart.			
	Bumpers must be removable and meet size (extend max. 4" horizontally on all sides and be located in the region 2" to 8" from the floor) and material constraints (no hard materials; if you can punch it and not hurt your hand, it's ok).			
	Decorations must be non-functional (cannot affect outcome of match).			
	Changeable rotating light (Red & Blue) easily accessible, visible from 4 sides of robot and mounted upright.			
	Wheels do not damage carpet. (No Velcro on wheels.)			
	Meets Additional Hardware list requirements.			
	No sharp objects that could harm people, damage balls or playing field.			
	Maximum of 5' latex tubing allowed to launch balls.			
	Springs only from Kit or SPI. Latex tubing use acceptable.			
	No excess lubricants that could contaminate field or balls.			
	The Robot Controller LED's are visible.			
	No tape used as a fastener. Only acceptable as an electrical insulator or decoration.			
	No illegal modification of control system components.			
	No loose wires or material to cause entanglement.			
	Battery is secured and easily removable.			
ELECTRICAL				
	Only 1 battery on robot.			
	Battery terminals must be insulated (electrical tape acceptable).			
	60A circuit breaker in series with battery (RED lead).			
	20 or 30A circuit breaker in series with each speed controller.			
	20A circuit breaker (on all remaining components) or fuses of equal or smaller value.			
	All Fisher-Price, drill, Mabuchi, Chiaphua, and Globe motors on one Innovation First speed controller each.			
	No more than one motor and 2 valves per relay module.			
	No more than one motor per speed controller.			
	Motor, pump or valve cannot be wired directly to junction block.			
	Custom circuit must be totally contained in BUD box.			
	Sensors wired to Robot Controller sensor port or custom circuit board only (no series connections with motors, etc. except a current-measuring input on custom circuit).			
	Proper wire color for constant polarity power distribution (red/white for positive, black for negative).			
	#6 wire from battery to junction block or fuse panel (battery -> battery fuse -> junction block or fuse panel).			
	#10 wire to speed controllers, Chiaphua motors, drill motors, Mabuchi Motor, and Fisher-Price motors.			
	#16 wire to Robot Controller logic power, valves, window motors, Globe motors, seat motors, Johnson motor, relays, large muffin fan, and rotating light.			
	#24 wire to switches, PWM cables, sensors, potentiometers, small muffin fans, and LED's.			
	No exposed electrical conductors.			
	No wires in electrical contact with robot metal chassis.			
	Proper use of electrical connectors and electrical tape.			
	No fabricated terminal strips (off the shelf terminal strips allowed per Additional Hardware list).			
	Team # set correctly on Robot Controller (power up RC via tether connection to check).			
	Rotating light must be on a relay that comes on/off when control system is enabled/disabled (power up RC to check).			
	Rotating light must be insulated from chassis and mounted on non-conductive surface.			
PNEUMATICS				
	All pneumatics parts are from the Kit / or from approved custom orders.			
	No modified pneumatics components.			
	No custom pneumatics components.			
	All air from compressor goes through regulator before any valves, cylinders, etc.			
	Pressure switch cannot be wired in series with the pump.			
	Regulator set to maximum of 60 psi.			